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Environment, Vegetation, and Regeneration After Timber Harvest in the Applegate Area of Southwestern Oregon

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Abstract

Multiple regression analyses are used to relate environmental factors and vegetation to postharvest forest regeneration in the Applegate area of southwestern Oregon. Optimal environments for regeneration were identified by aspect, slope, elevation, rock cover, and vegetation.

Keywords: Regeneration (natural), regeneration (artificial), ecology (plant), silvicultural systems, environment.

Introduction

The Applegate area is located south and west of Medford in the eastern Siskiyou Mountains, Oregon. We studied that portion of the area bounded on the north and east by the Rogue River and Bear Creek Valleys, on the west by Williams Creek, and on the south by a line drawn between McDonald Peak and Steamboat Mountain (fig. 1). We did not include the Mount Ashland area studied by Waring (1969).

Steep slopes, broken topography, and great variation in soils combine to produce an intricate mosaic of interacting environmental factors in the Applegate area. Its diverse flora includes plant species usually found in northwestern Oregon, eastern Oregon, or California. Fires have added complexity by creating an array of stand ages and seral plant communities.

We studied the environment and forest regeneration to derive functional relationships between selected environmental factors and postharvest regeneration in clearcut and partial cut areas. These relationships were developed for public land managed by the Bureau of Land Management (BLM), U.S. Department of the Interior, but they should be useful on land of all ownerships in the study area. Our objective was to compare forested sites in terms of relative difficulty of regeneration.

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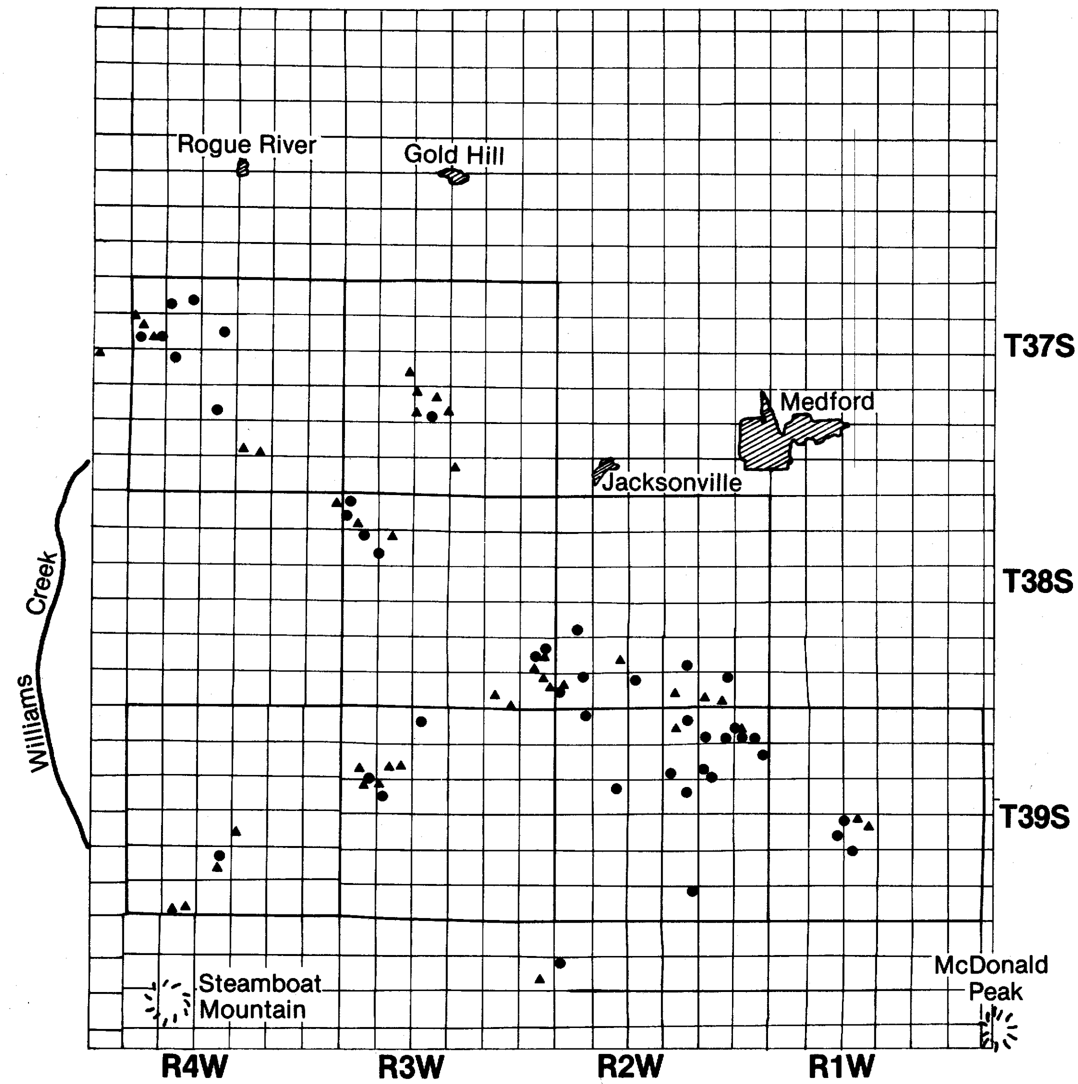

Figure 1.—Locations of sample plots in the Applegate area. Triangles indicate clearcuts. Circles indicate partial cuts.

Methods

Clearcuts

We sampled 40 clearcut units during 1977 (fig. 1), using every accessible BLM clearcut in the Applegate area. Approximate ages of these units were determined from sale records. Within each clearcut, we then sampled 1 acre (0.4 ha) of uniform slope and aspect, using a grid of 30 circular 1/250-acre (0.0016 ha) subplots spaced 33 feet (10 m) apart.[1] Postharvest seedlings were counted and subplots recorded as stocked if seedlings were established.[2] Slash cover, rock cover, and dominant herbaceous plant species were estimated on each subplot. The dominant shrubs and trees within 15 feet (4.6 m) of the center of each subplot were noted and tallied. We considered vegetation on clearcuts too disturbed to be used as an environmental indicator.

We determined elevations with an altimeter calibrated daily against known benchmarks, and measured slope with an Abney level and aspect with a compass. Slope and aspect figures were then used with the tables of Frank and Lee (1966) to obtain a radiation index for each area sampled. We coded the aspect azimuths by determining an optimum azimuth as described by Stage (1976), then used this optimum as a maximum in the aspect transformation equation published by Beers et al. (1966).

We used a single soil pit 10 inches (25 cm) deep to measure soil pH (Helige-Truog kit), percent silt + clay (Cenco-Wilde field kit), and soil color (Munsell color charts).[3] We coded the Munsell hue, value, and chroma values and obtained total soil depth by digging to the C horizon or to 50 inches (127 cm). A single soil sample for each clearcut unit was collected at 10 inches (25 cm), air dried, and sent to the laboratory in Corvallis. There cation exchange capacity, total nitrogen, acid extractable phosphorus, soluble potassium, soluble calcium, and soluble magnesium contents were determined by standard analytical methods.

We subjected all of the quantitative environmental variables to two stepwise multiple regression analyses—one with stocking percent as the dependent variable and the other with number of seedlings per acre as the dependent variable. Environmental variables with significant coefficients ($p<0.05$) were retained in the resulting multiple regression equations. The equations accounting for the most variation are presented here as mathematical models for comparing forest sites in terms of regeneration after clearcutting.

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[1] Topographic variation limited the sample size to less than 30 subplots in several extremely irregular clearcut units.

[2] We considered Douglas-fir and white fir seedlings established if branching occured before 1977. Establishment of other conifers was judged by size and vigor. One or more established seedlings were required to stock a subplot.

[3] The mention of products does not imply endorsement by the U.S. Department of Agriculture to the exclusion of other products that might be suitable.

Partial Cuts

We sampled 41 partially cut stands in the Applegate area during 1977 and 1978 (fig. 1). Cutting dates were determined by examining sale contracts. Elevations were determined with a calibrated altimeter. We used the subplot grid previously described for clearcut sampling, with thirty 1/250-acre (0.0016-ha) subplots spaced 33 feet (10 m) apart. Uniform slope and aspect conditions on areas large enough to accommodate our sample grid were exceedingly difficult to locate in partial cuts, however, and small variations in slope and aspect were accepted. We recorded the slope and aspect of each subplot and averaged them for the entire subplot grid.[4/] Seedling and stocking criteria were the same as used in the clearcut areas.

As with the clearcuts, we estimated slash and rock cover on each subplot. Estimates of gravel cover and duff depth were added, and we recorded every herbaceous plant species found on each subplot.

We tallied shrub species found within 15 feet (4.6 m) of subplot centers. Trees within the same circles were also recorded, unless they were counted in the basal area measurements of the overstory.

We measured basal area of the residual stand with a 20-factor prism, by species, from each subplot center. Overstory density was determined in three ways: We dot-counted the canopy density in four directions with a spherical densiometer, estimated overhead canopy density by sighting through a tube formed by a 10¾ oz (305 g) soup can with ends removed, and estimated average overstory crown spacing.

At each subplot center, we recorded species, diameter, and age of the nearest conifer at least 4.5 feet (1.4 m) tall. Age was determined by counting increment core rings. We evaluated release after cutting by examining the increment cores.

The soil sampling procedure previously described for clearcut units was modified to obtain a better sample in the partially cut stands. We dug four 20-inch (51-cm) soil pits in each stand (at subplots 6, 12, 18, and 24), then collected soil samples at 10 inches (25 cm), and estimated coarse fragment content in both the A horizon and the total 20-inch (51-cm) profile. Equal volumes from each of the four soil samples were blended in a single sample from each stand for laboratory analysis and determining texture in the field. Soil depth in each stand was determined by digging a single pit to the C horizon or 50 inches (127 cm).

Soil analyses were the same as those used for clearcut soils, but the pH and color measurements were omitted after we found they were not useful in the clearcut units. Silt and clay content were measured both in the field (Cenco-Wilde kit) and in the laboratory (particle size analyses of silt, clay, and sand).

We derived temperature indices for each partially cut stand by correlating the presence of indicator species and air temperatures from May through August 1978 on 18 undisturbed stands distributed over a wide range of elevations and aspects in the study area. Temperatures were measured with shielded recording thermographs and maximum-minimum thermometers at 8 inches (20 cm) above the soil surface. We used the procedures described by Warner and Harper (1972) to select plant indicators and assign indicator values.

[4/] Average azimuths were coded for regression analyses by using the procedure described for clearcut azimuths.

We also derived moisture indices for the partially cut stands. Plant indicators were selected and weighted by using the Warner and Harper procedure with measured moisture values and data on species presence. The moisture values were plant moisture stresses measured on 42 independent, undisturbed plots during August 1977 by procedures described by Waring and Cleary (1967).

A vegetation index was calculated for each of the 41 partially cut stands sampled by the procedure described by Minore and Carkin (1978).

Our measurements were subjected to stepwise multiple regression analyses, using stocking percent and number of seedlings as dependent variables and including only independent variables with significant coefficients in the equations. We plotted one of these equations as a series of curves to illustrate environmental differences among partially cut stands.

Results

Clearcuts

The 40 sample clearcut areas ranged in age from 10 to 18 years in 1977, but age was not significantly correlated with stocking.[5] Most areas were steep (fig. 2). Although most (25) faced north, northeast, or northwest, 9 had aspect azimuths between 90° and 270°. The remaining six areas had east-northeast or west-northwest aspects. Aspect codes based on the calculated optimum azimuth of 2° are listed in table 1.

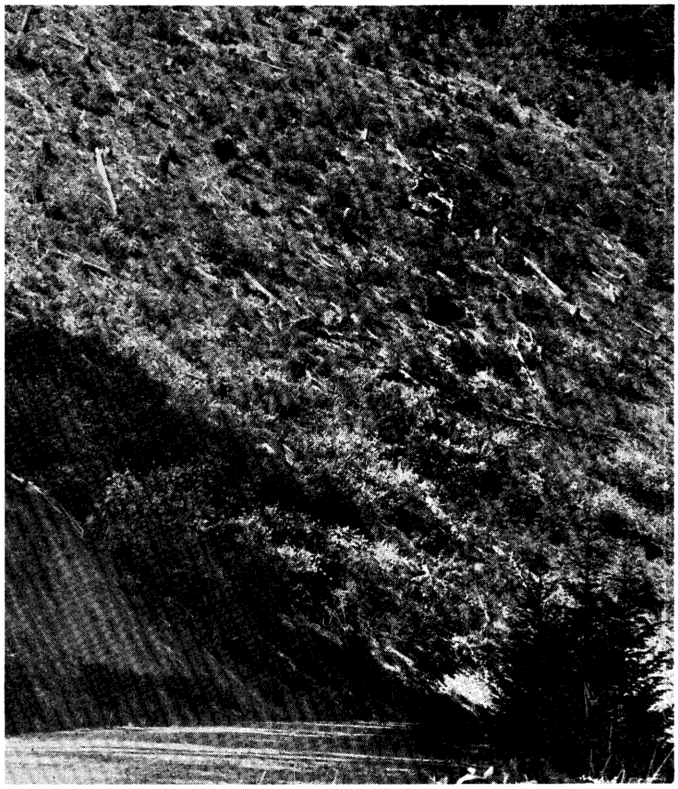

Figure 2.—A typically steep clearcut unit in the Applegate area.

[5] The stocking percentages used here are based on the number of stocked subplots divided by the total number of subplots. The subplots are 1/250 acre (0.0016 ha), and a stocked subplot contains one or more established seedlings. Different sizes of subplot or stocking standards would yield different percentages but similar relative differences among clearcut areas.

Table 1—Aspect codes for Applegate area clearcuts (optimum = 2° azimuth)

Azimuth	Aspect code	Azimuth	Aspect code
0°	2.00	180°	0.00
5°	2.00	185°	0.00
10°	1.99	190°	0.01
15°	1.97	195°	0.02
20°	1.95	200°	0.05
25°	1.92	205°	0.08
30°	1.88	210°	0.12
35°	1.84	215°	0.16
40°	1.79	220°	0.21
45°	1.73	225°	0.27
50°	1.67	230°	0.33
55°	1.60	235°	0.40
60°	1.53	240°	0.47
65°	1.45	245°	0.55
70°	1.37	250°	0.62
75°	1.29	255°	0.71
80°	1.21	260°	0.79
85°	1.12	265°	0.88
90°	1.03	270°	0.96
95°	0.95	275°	1.05
100°	0.86	280°	1.14
105°	0.78	285°	1.22
110°	0.69	290°	1.31
115°	0.61	295°	1.39
120°	0.53	300°	1.47
125°	0.46	305°	1.54
130°	0.38	310°	1.62
135°	0.32	315°	1.68
140°	0.26	320°	1.74
145°	0.20	325°	1.80
150°	0.15	330°	1.85
155°	0.11	335°	1.89
160°	0.07	340°	1.93
165°	0.04	345°	1.96
170°	0.02	350°	1.98
175°	0.01	355°	1.99

Ranges and averages of variables found to be important in clearcuts were as follows:

	Stocking	Elevation		Slope	Aspect code	Soil depth
	(Percent)	*(Meters)*	*(Feet)*	*(Percent)*	(from table I)	*(Centimeters)*
Range	10-100	671-1 463	2,200-4,800	33-79	0.02-2.00	30-127+
Average	62	1 031	3,382	67	1.53	107

Dominant trees competing with conifer regeneration on the clearcut units include Pacific madrone (*Arbutus menziesii* (Pursh))[6] (10 units) and canyon live oak (*Quercus chrysolepis* (Liebm.)) (11 units). Most of the madrone was on northeast aspects and deep soils. Canyon live oak occurred on all aspects and soil depths but appeared more frequently on shallow soils.

[6] Nomenclature is according to Garrison et al. (1976).

Dominant shrubs on the clearcuts included hazel (*Corylus cornuta* Marsh.) (11 units) and creambush rockspirea (*Holodiscus discolor* (Pursh) Maxim.) (3 units) on north and east aspects, redstem ceanothus (*Ceanothus sanquineus* Pursh) (4 units) on west and northwest aspects, and three shrubs that were dominants on several aspects—snowberry (*Symphoricarpos* spp.) (7 units), deerbrush ceanothus (*Ceanothus integerrimus* H. and A.) (5 units), and winter currant (*Ribes sanquineum* Pursh) (3 units). Snowberry and redstem ceanothus were found as dominants only on deep soils, usually at low radiation indices. In contrast, deerbrush ceanothus was dominant only on shallow soils, usually at high radiation indices.

Grasses dominated the herbaceous vegetation on more than half the clearcut areas sampled. They did not appear to vary consistently with most of the environmental variables measured. Soil calcium may be associated with grass dominance, however; average calcium content was 0.259 percent (standard error = 0.023) for the 23 grass-dominated clearcut areas. It was only 0.167 percent (standard error = 0.054) for the 10 areas dominated by whipple vine *(Whipplea modesta* Torr.) The four clearcut areas dominated by Pacific peavine (*Lathyrus polyphyllus* Nutt. ex T. and G.) had an average soil calcium content of 0.312 percent (standard error = 0.048).

We recognized eight plant communities on the sample clearcut areas:

Corylus/grass
Corylus/Whipplea
Corylus/Lathyrus polyphyllus
Symphoricarpos/grass
Symphoricarpos/Whipplea
Ceanothus sanquineus/Whipplea
Ceanothus integerrimus/grass
Ribes sanguineum/grass.

All of these communities are seral in nature. None were consistently associated with regeneration differences among the clearcut units.

Several of the measured environmental variables were significantly associated with differences in regeneration. Aspect code was positively correlated with regeneration success ($r = 0.607$). Radiation index ($r = -0.535$) and rock cover class ($r = -0.368$) were negatively correlated.

Initial stepwise multiple regression analyses using number of seedlings as the dependent variable accounted for less variation than those using stocking percent, so we used stocking percent as the dependent variable in subsequent analyses. The best multiple regression, made up of only significant regression coefficients, accounted for 58 percent of the total variation:

$$\begin{aligned}\text{Relative stocking percent} = {} & 2.53103 + 33.7774\ (\text{aspect code}) + 0.531789\ (\text{silt + clay percent}) \\ & + 0.179901\ (\text{soil depth, cm}) + 6726.97\ (\text{phosphorus percent}) \\ & - 0.000575011\ (\text{elevation in meters x slope percent})\end{aligned}$$

$R^2 = 0.582$.

Standard error of estimate = 18.0 percent.

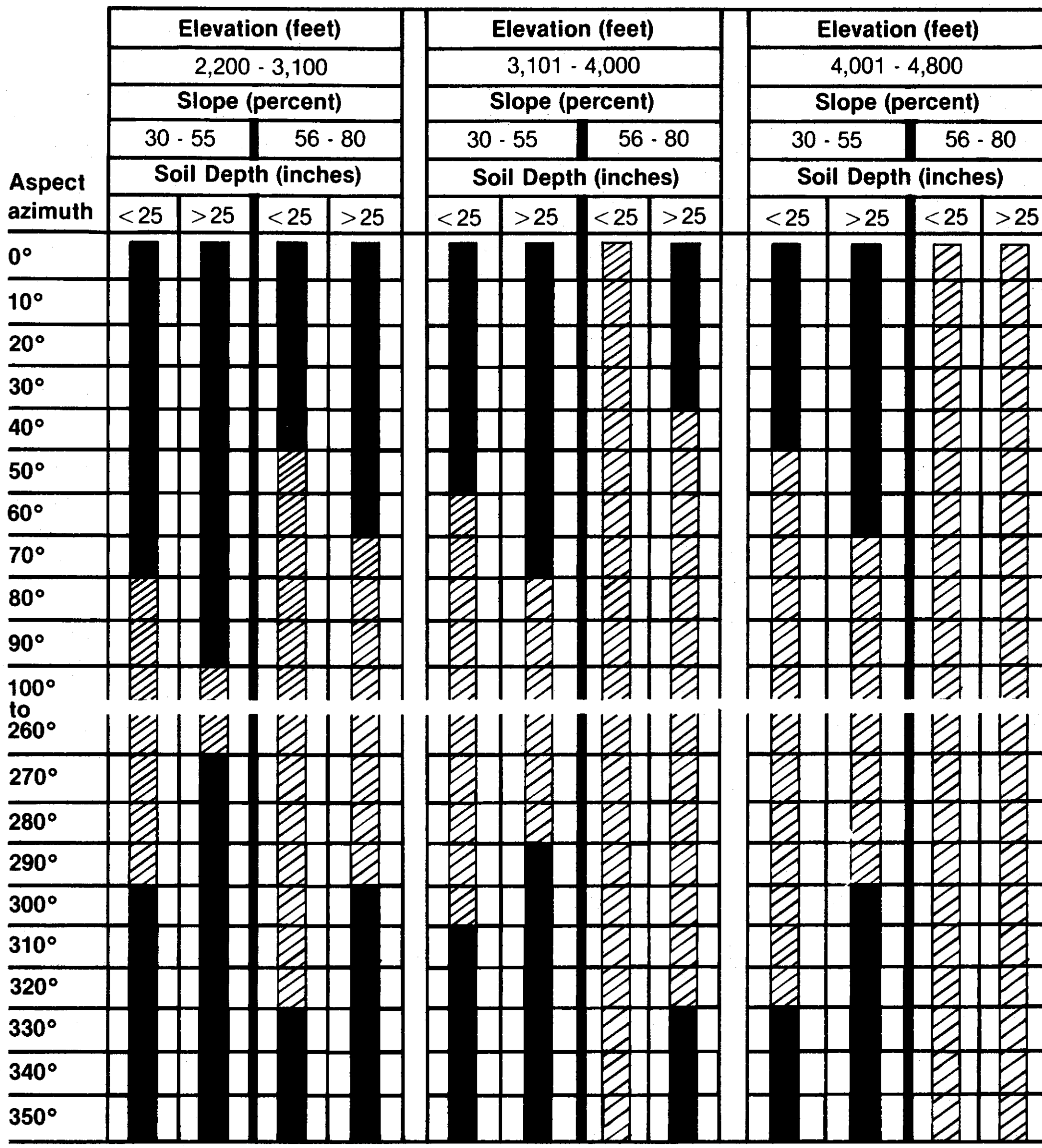

Figure 3.—Optimal environments for regeneration of Applegate area clearcuts in relation to aspect, elevation, slope, and soil depth. Solid bars indicate relative stocking of 60 percent or better; cross-hatched bars indicate less than 60 percent. Relative stocking percent = 33.7623 + 31.1419 (aspect code) + 0.54355 (soil depth in inches) - 0.000186056 (elevation in feet x slope percent). $R^2 = 0.515$.

The time and expense associated with soil analyses may not be acceptable to field foresters who need to compare forest sites without waiting several months for laboratory results, so we selected another, less precise but more convenient, multiple regression equation for field use:

$$\begin{aligned}\text{Relative stocking percent} = {} & 33.7623 + 31.1419 \text{ (aspect code)} \\ & + 0.213996 \text{ (soil depth, cm)} \\ & - 0.000610418 \text{ (elevation in meters x slope percent)}\end{aligned}$$

$R^2 = 0.515$

Standard error of estimate = 18.9 percent.

This second equation was transformed to English units (feet and inches) and used as a mathematical model in constructing figure 3, which can be used as a guide in selecting optimal environments for clearcutting in the Applegate area.

Figure 3 and the multiple regression equations are based on environmental measurements. They do not account for differences in site preparation, planting techniques, or condition of planting stock among the clearcut areas, and they do not reflect recent improvements in reforestation technology. Differences in reforestation techniques and improvements in technology do not change the environments in which they are applied, but they may modify environmental effects and increase regeneration success (stocking percent). Our relative stocking percentages indicate the relative severity of clearcut environments, not the potential stocking rates that would be obtained if current reforestation technology were properly applied.

Partial Cuts

Underplanted partial cuts were not available in the sample area, and all regeneration tallied was of natural origin (fig. 4). Elevations varied from 1,700 to 4,800 feet (518 to 1 463 m), but stocking was not correlated with elevation. Although cutting dates ranged from April 1958 through April 1975, regeneration was not significantly correlated with time since cutting. Aspect codes (table 1) were positively correlated with regeneration success, and radiation indices were negatively correlated, but neither variable was important enough to be retained in significant stepwise multiple regression equations.

Ranges and averages of variables found to be important in partial cuts were as follows:

	Stocking	Vegetation index	Rock cover	Calcium
	(Percent)	(From table 2)	*(Percent)*	*(Percent)*
Range	3-97	3.0-12.4	0-50	0.026-0.192
Average	46	8.9	8	0.103

Douglas-fir *(Pseudotsuga menziesii* (Mirb.) Franco) dominated the overstory stand in most partial cuts sampled, but white fir *(Abies concolor* (Gord. and Glend.) Lindl. ex Hildebr.) was codominant or dominant in four of the stands located at elevations above 3,600 feet (1 100 m). Ponderosa pine *(Pinus ponderosa* Dougl. ex Loud.) was codominant in two other stands, and appreciable amounts of Pacific madrone occurred in the overstory canopies of four more.

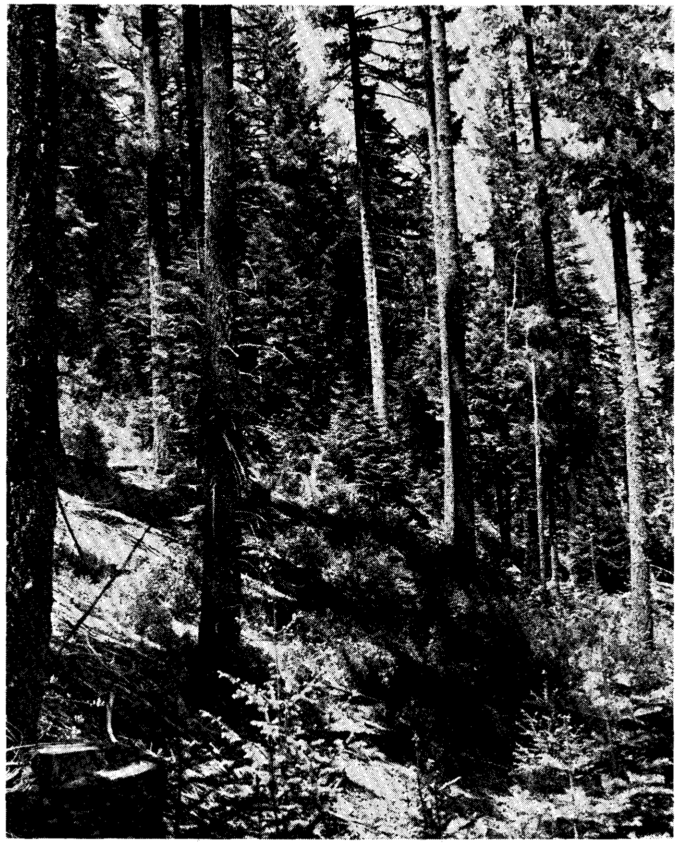

Figure 4.—Abundant natural regeneration in a partially cut stand.

The following plant communities were encountered in two or more partially cut sample stands:

Pseudotsuga/Berberis aquifolium
Pseudotsuga/Berberis nervosa
Pseudotsuga/Corylus
Pseudotsuga/Holodiscus
Pseudotsuga/Lonicera hispidula
Pseudotsuga/Symphoricarpos

With the exception of the three *Pseudotsuga/Berberis nervosa* stands (all adequately stocked), none of these community types appeared to be related to regeneration. Stands on the shallow, gravelly 701 and 825 soils (deMoulin, et al. 1975) tended to be understocked, but soil series also were poorly correlated with forest regeneration.

Neither canopy density nor overstory basal area were significantly correlated with postharvest regeneration in the sample partial cuts. Our field observations indicate that this probably is a result of irregular cutting in residual stands sampled. Heavy cutting at some subplots and light cutting at other subplots resulted in large variations in canopy and basal area within each sample stand. When these greatly varying values were averaged and the different stands were compared, no statistically significant relationships of overstory to regeneration were obtained.

Individual subplots with radiation indices below 0.3500 had more postharvest seedlings where overstory basal areas were 20-100 square feet per acre (4.6-23 m^2/ha), however, and those with radiation indices above 0.3500 had more seedlings where basal areas were greater than 80 square feet per acre (18.4 m^2/ha). Most of the partial cut regeneration occurred under overstory canopy densities of 45 to 75 percent.

Regeneration was much more abundant on tractor-road fills than on adjoining areas. Ponderosa pine seedlings seemed to be more successful than Douglas-fir seedlings on the central, compacted portions of these roads. We also observed that Douglas-fir regeneration was often better under madrone canopies than it was under comparable Douglas-fir canopies at elevations above 2,600 feet (800 m).

Three stand age categories were evident in the Applegate area: even-age (15 sample stands), two-age (11 stands), and uneven-age (15 stands). Most of the even-age and two-age stands were poorly stocked with postharvest regeneration. Most of the uneven-age stands were well stocked.

Our age data indicate that favorable regeneration conditions in the Applegate area have occurred at approximately 30-year intervals: in 1790, 1820, 1850, 1880, 1910, and 1950. These favorable conditions may have resulted from local fires, unusual weather, or good seed crops. Absence of definite age classes in the uneven-age stands, however, suggests that fire—not weather or seed crops—probably was associated with past regeneration success in the even-age and two-age stands.

The uneven-age stands are characterized by great variations in age and diameter, but small young trees are more numerous than large old ones, and stand diameter distributions closely resemble the exponential functions typical of uneven-age structure. Estimated ages at breast height range from 1 to 350 years, with an average within-stand age range of 245 years in the 15 uneven-age stands sampled.

We noted an abrupt reduction in growth at 35-45 years (breast height age) in most trees sampled. After partial cutting, 55 percent of the sound, undamaged sample trees accelerated growth, putting on wider annual rings. We were unable to discover why some trees in a stand grew faster after partial cutting and others did not, but stands reacted differently. These stand differences were associated with temperature indices derived from the presence of indicator species (table 2):

Release percent = 88.14 - 4.95 (temperature index)

$R^2 = 0.34$.

Similar relationships with moisture indices derived from the presence of indicator species were calculated. White fir basal area, duff depth, and soil calcium all increased as the moisture index increased. Basal areas of incense-cedar (*Libocedrus decurrens* Torr.) and California black oak (*Quercus kelloggii* Newb.) decreased with increasing moisure. We noted that incense-cedar was able to grow in very wet areas, however, such as perennial creek bottoms.

Table 2—Indicator species and values used in estimating relative temperature conditions in undisturbed and partially cut Applegate area stands [1]

Species	Indicator value [2]
Ceanothus integerrimus	13
Aster radulinus Gray	12
Eriophyllum lanatum (Pursh) Forbes	12
Quercus garryana Dougl.	12
Goodyera oblongifolia Raf.	2
Polystichum munitum (Kaulf.) Presl.	2
Rubus ursinus Cham. and Schlecht.	1

[1] A temperature index may be obtained by averaging the values of all species present in a given stand.

[2] High values indicate warm temperatures. Low values indicate cool temperatures.

Several other significant correlations illustrate general relationships among the environmental variables measured. They are summarized in table 3. Vegetation indices calculated by using the indicator species listed in table 4 are highly correlated with regeneration stocking percent ($r = 0.729$).

When all variables were related to regeneration stocking percent by stepwise multiple regression, the best significant coefficient equation accounted for 71 percent of all variation:

$$\text{Relative stocking percent} = 24.2292 - 0.920835\,(\text{rock cover percent}) - 115.271\,\text{calcium percent}) + 0.471737\,(\text{vegetation index})^2$$

$R^2 = 0.710$.

Standard error of estimate = 14.84 percent.

Because determining soil calcium requires laboratory analyses that are time consuming and not readily available to many field foresters, another, less accurate equation was derived at an earlier stage of our stepwise multiple regression analyses. This equation accounted for two-thirds of the total variation and utilized variables that can be rapidly and easily estimated in the field:

$$\text{Relative stocking percent} = 10.8476 - 0.937655\,(\text{rock cover percent}) + 0.490919\,(\text{vegetation index})^2$$

$R^2 = 0.676$.

Standard error of estimate = 15.46 percent.

Representative values were used with this equation to construct curves that illustrate relative stocking levels under various vegetation and rock cover conditions (fig. 5). They can be used in the field to compare Applegate area environments in terms of relative natural regeneration success after partial cutting.

Table 3—Significant correlations among environmental variables in the Applegate area [1]

Variable	Slope percent	Elevation	Aspect code	Radiation index
Temperature index	-0.531**	-0.466**	-0.529**	0.593**
Moisture index		0.544**		
Rock cover	0.395*			
Gravel cover	0.461**			
Duff depth		0.458**		
Coarse fragments, 20 inches	0.493**	0.398*		

[1] Significance of the correlation coefficients is indicated by *(P<0.05) and **(P<0.01).

Table 4—Indicator species and values used for comparing Applegate area sites in terms of natural forest regeneration expected after partial cutting [1]

Species	Values [2]
Cardamine integrifolia (Nutt.) Greene	15
Ceanothus sanguineus	15
Quercus chrysolepis	15
Rubus ursinus	15
Erythronium hendersonii Wats.	14
Melica geyeri Munro	14
Ribes sanguineum	14
Arbutus menziesii	13
Arnica latifolia Bong.	13
Chimaphila menziesii (R. Br.) Spreng.	13
Disporum hookeri (Torr.) Nicholson	13
Heuchera micrantha Dougl. ex Lindl.	13
Lithophragma spp.	13
Luzula campestris (L.) DC.	8
Trientalis latifolia Hock.	8
Amelanchier alnifolia Nutt.	4
Collinsia parviflora Lindl.	4
Collomia grandiflora Dougl. ex Lindl.	4
Collomia heterophylla Hock.	4
Festuca rubra L.	4
Lonicera ciliosa (Pursh) DC.	4
Prunus spp.	4
Sedum spp.	4
Sidalcea virgata Howell	4
Epilobium minutum Lindl. ex Hook.	3
Potentilla spp.	3
Brodiaea spp.	2
Clarkia spp.	2
Quercus garryana Dougl.	1

[1] A vegetation index may be obtained by averaging the values of all species present in a given stand.
[2] High values indicate relatively good regeneration sites. Low values indicate relatively poor regeneration sites.

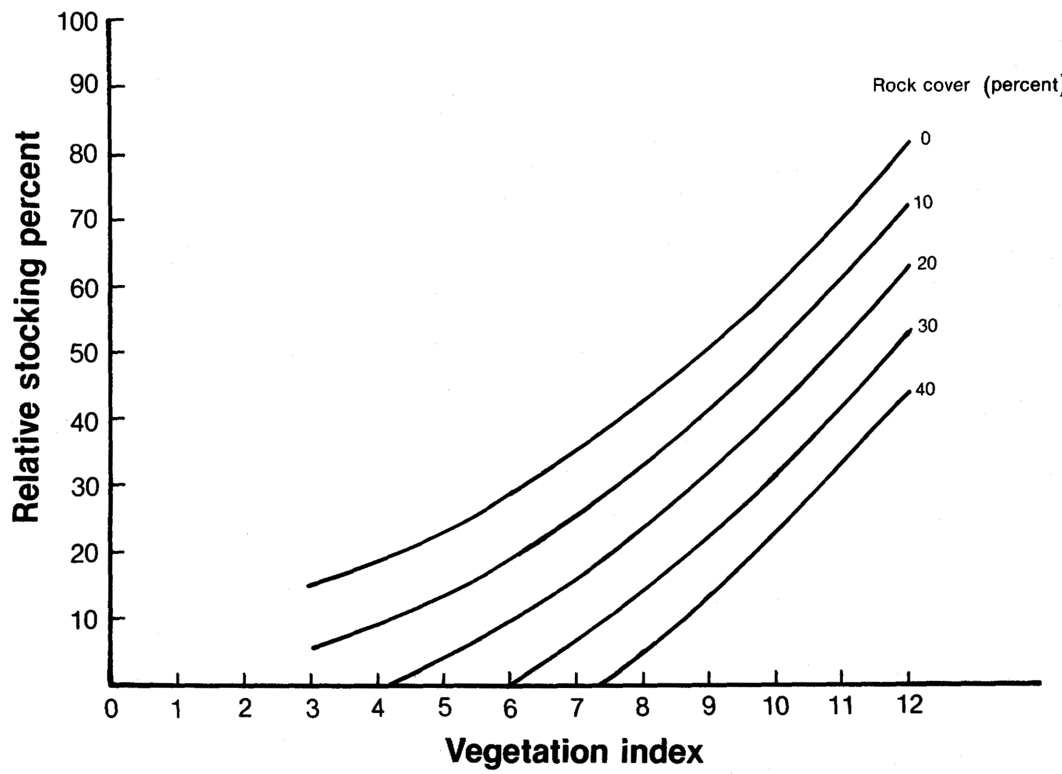

Figure 5.—Relation of vegetation index to relative stocking percent at five rock cover percentages in Applegate area partial cuts.

Conclusions

Forest regeneration in the Applegate area is significantly related to aspect, slope, elevation, soil depth, and surface rock cover. Gently sloping northern aspects on deep soils at elevations below 4,000 ft (1 219 m) are optimal for clearcut regeneration. Natural regeneration after partial cutting is best where there is little rock cover and the vegetation includes more species with high indicator values than species with low values (table 4).

Residual trees often respond to partial cutting by increasing radial growth. This response occurs most often on cool sites with low radiation indices. Hot sites with high radiation indices require more residual overstory than cool sites if natural regeneration is to be obtained. Seed crops are erratic, however, and underplanting is recommended where prompt regeneration is required.

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